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**Washington State University's
Independent Evaluation of Air Quality Impacts from
Agricultural Burning In Eastern Washington**

**Final Report
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Introduction

For years, growers in eastern Washington State have been using fire as a tool to clear fields, control weeds and disease, and prepare the ground for seeding. Although grass seed field burning was discontinued in 1998 in Washington State, cereal crop growers still use prescribed burning as a farming tool. This practice leads to occasional smoke impacts on neighboring and downwind communities, along with citizen complaints. There have been anecdotal accounts of moderate to severe health impacts due to the smoke, however the health effects associated with exposure to cereal crop stubble burning have not yet been quantified. Indeed, the air quality impacts due to agricultural burning in this region have only recently been measured. Measurements taken from semi-continuous particulate matter monitors (TEOMs) in northern Idaho have occasionally shown very high hourly concentrations of both PM₁₀ and PM_{2.5}, however because of the short duration that is typical of smoke impacts from field burning, seldom is there an exceedance of the 24-hr PM standards. Identifying the impacts from agricultural burning in eastern Washington is complicated by agricultural burning in Idaho (particularly grass seed field burning in northern Idaho and on the Coeur d'Alene Reservation), as well as smoke from regional forest fires – either wild or prescribed. Finally, the PM emission factors and smoke behavior (e.g., plume rise) are not well-understood for agricultural smoke, making dispersion modeling difficult at this time, although there has been some progress recently in determination of emission factors for agricultural burning.

In this project, the air quality impacts primarily in the Pullman area due to agricultural field burning in Washington state were examined. Specifically, the objectives of this work were to determine the frequency of smoke from agricultural burning impacting air quality in Pullman, to characterize the severity of the air quality impact, and to identify the source of the smoke leading to the impact. Periods of possible smoke intrusion were identified from the available particulate matter data; burn periods were identified from permit records and post-burn reports; complaint logs were examined for comparison to the air quality data and permit information; and trajectory and dispersion modeling was conducted for smoke intrusion dates to link observed smoke impacts to agricultural burning in eastern Washington and/or northern Idaho. This work focused on the spring and fall burn seasons in 2000 and 2001.

Methods

Generally, the approach taken in this investigation was as follows:

1. Identify periods of possible smoke intrusion from the air quality data,
2. Identify possible burn periods from permit records and burn calls,
3. Identify actual burn periods from post-burn reports and compare to the smoke intrusion events,
4. Examine transport of smoke on a given day using a combination of trajectory analysis and dispersion modeling,
5. Look at satellite pictures for other evidence of fires and their locations, and
6. Compare complaint logs to these above results to determine how often agricultural smoke was correctly identified as the source of the smoke.

Burn Permits, Burn Calls, and Post-Burn Reports

In 2000, post-burn reports were voluntarily submitted by growers; in 2001, these reports were required. The post burn report summarizes the location of the fire, the number of acres burned, and the date, time, and meteorological conditions of the burn. Thus, for 2001, there was more complete information on the date, timing, and number of acres burned, making it easier to characterize the air quality impacts specifically from cereal residue burning in eastern Washington State.

Burn calls were obtained from Washington Department of Ecology for both 2000 and 2001. From these data, the available windows for agricultural burning, by county and season, were determined.

Copies of burn permit applications were also provided by WDOE. From the applications in 2000, the information recorded for this investigation included location and size (number of acres) of the intended burn, as well as the target date for burn. The burn application requires a fee payment that is proportional to the number of acres burned. Burn permit information in 2000 was very vague – in some cases, the application was considered for both fall and spring burn seasons. Additionally, in 2000 the number of acres indicated by the applications did not correspond to the number of acres actually burned. In the case where the grower did not use the permit, the permit fees could be refunded. In 2000, WDOE initiated a voluntary program in which growers were asked to return information after their burn, however the response rate was low. So, the actual number of acres burned was estimated from the applications, less the refunded permit fees.

Complaint Logs

WDOE operates an air quality hotline to which citizens can report any air quality incident, including smoke from agricultural, forestry, or other burn operations. The complaint logs for the years 2000 and 2001 were obtained for this study, for comparison to the information on Washington agricultural burns, with the purposes of determining: 1) the source of the smoke that triggered the complaint, 2) whether the complaint accurately identified the source of the smoke, 3) if burns took place in locations for which burns were not allowed (no burn calls), and 4) if burn calls allowed burns that subsequently led to citizen complaints.

Trajectory Analyses

To determine the origin of air parcels arriving at particular locations during identified smoke episodes, back-trajectories were calculated by hand, and using the NOAA HYSPLIT model (Draxler and Hess, 1998). HYSPLIT, which is available on the NOAA website (<http://www.arl.noaa.gov/ss/models/hysplit.html>), calculates forward or backward trajectories, as well as dispersion and concentrations. For modeling historical dates, HYSPLIT uses archived forecast meteorological data generated by the National Weather Service's National Center for Environmental Prediction (NCEP). For the purposes of this work, two archives of forecast data are available: Global Data Assimilation System (GDAS), and ETA Data Assimilation System (EDAS). These data sets differ in the horizontal, vertical, and temporal resolution. The EDAS grid covers the continental US and has a horizontal resolution of 80 km. The other grid covers both hemispheres and has a horizontal resolution of 191 km.

Since HYSPLIT uses archived forecast meteorological data, manually calculated trajectory analyses were also performed for a limited number of days using archived meteorological observations.

Results and Discussion

Air Quality

In general, the nephelometers at Pullman and at Colfax showed similar results in 2000. PM_{2.5} concentrations for April, May, June, July, August, September, and October 2000 for both Pullman and Colfax were typically under the 24-hr PM_{2.5} standard of 65 ug/m³, and in fact were usually also under the annual average of 25 ug/m³. Peak hourly concentrations over 40 ug/m³ were recorded for the following dates in 2000: June 29; July 22; August 23; September 14; October 9; and October 26.

In 2001, the monitor in Colfax was no longer available, however a TEOM with PM_{2.5} inlet was located in Moscow, ID, and another TEOM with PM_{2.5} inlet was operated on the top of Dana Hall by WSU. During the fall of 2001, several instances of high PM_{2.5} concentrations were observed in Pullman, especially on September 12 and September 19.

Burn Calls, Burn Permits and Post-Burn Reports

In 2000, in eastern Washington, there were 1502 burn applications submitted, for 2,606 individual burns involving more than 190,000 acres. Most of the applications were from Whitman, Walla Walla and Columbia counties (67% of the burn applications and 84% of the numbers of acres). Most of these applications were approved (99.7%). Based upon the permit fee refund information, approximately 166,000 acres were actually burned in 2000. The post-burn reports from the fall of 2000 reported only 38,966 acres burned, indicating that the grower response to the voluntary program was not very good (approximately 40% of acres permitted were actually reported as being burned).

In 2001 the mandatory post-burn reporting procedure was implemented, and a much higher total acreage was reported as being burned (although the total number of acres burned was lower in 2001 compared to the estimate for 2000). In total, 126,285 acres were reported as burned in 2001, of which over 99,000 acres were reported for spring 2001. Whitman, Columbia, and Walla Walla counties account for 86% of the total acreage burned. Most of the spring activity occurred during the months of March and April.

It is instructive to compare the number of days each season in which burning was allowed to the number of acres burned per season. In 2000, the burn calendar for eastern Washington allowed 97 days in which agricultural burning was allowed. Most of these days (70 days) were in the spring. Based upon permit information, the number of acres was evenly distributed between spring and fall, so that average number of acres burned per day would be much higher in the fall compared to the spring. When the burn days (as called by WDOE) are examined by county, Columbia County had a smaller number of approved burn days but the largest number of acres burned. We suspect this is in part due to the extension agent making burn calls in Columbia County in 2000 and so these burn days were not being recorded as such. In 2001, there were

fewer burn days (89 in 2001 compared to 97 in 2000), similarly distributed between spring and fall.

Complaint Log

In 2000, there were 76 formal complaints registered in eastern Washington. These were related to agricultural burning (20), orchard take-out burning (14), open burns (39), or other (3). Most of these complaints were for the fall (59 fall vs. 17 spring), and came from 12 counties, with three (Franklin, Whitman and Stevens) reporting 60% of the total complaints for the year. The 26 complaints from Franklin County were anonymous and were not specific regarding the source or reason for the protest. Of the 11 complaints from Whitman County, 4 reported bad air quality conditions (smoke from agriculture was specified), 5 reported agricultural burning activities, 1 reported dust, and the last reported open burning. In Stevens County, 7 of the 9 complaints reported open burning. Table 1 summarizes the complaints in eastern Washington for both 2000 and 2001.

Table 1. Sources of Air Pollution Reported and Reason for Protest from Complaint Log, 2000 and 2001

Reason	Agricultural or Orchard Burning		Open		Other		Total	
	2000	2001	2000	2001	2000	2001	2000	2001
Burning activities	15	11	15	40	1	4	31	55
Smoke in the air	7	17	8	11	1	44	16	72
Other/not relevant	12	3	21	3	1	9	34	15
Total	34	31	44	54	3	57	76*	135*

* these numbers do not sum to the totals indicated for each year, because some complaints were for both burning activities and smoke in the air, for example.

In 2001, there was an overall increase in the number with 135 formal complaints registered, of which 23 were regarding agricultural burning, 11 were with respect to orchard burning, 46 were about open burning, 35 were general complaints, and 20 were other. We suspect that part of this increase in numbers of complaints is due to increased public awareness of the air quality hotline. There were large increases in the number of complaints from Spokane, Whitman, and Stevens Counties, and a large decrease in the number of complaints from Franklin County. In both 2000 and 2001, the majority of complaints were registered between the months of August – December.

In order to determine whether the source of the complaint was detected at the air quality monitoring site, the daily mean and peak PM_{2.5} concentrations from the nephelometer in downtown Pullman were compared to the complaint occurrences from Pullman. The results are shown in Table 2, below. There were 18 complaints on days for which the peak, hourly PM_{2.5} as measured at the Pullman nephelometer did not exceed 20 ug/m³. For these two years, there were 11 complaints for which the peak, hourly PM_{2.5} measured at the Pullman nephelometer did exceed 20 ug/m³. There are several possibilities that might help to explain this apparent

“disconnect”. First, it is possible that the spatial variability of agricultural burning leads to PM2.5 “hot spots” so that a fixed monitoring site may or may not be impacted by the smoke. Second, it is possible that the complaints were responding to some other air pollutant rather than PM2.5 – for example, oxygenated hydrocarbons that can be detected by smell. Third, is it possible that the complaints responded to visual observations of smoke rather than air quality impacts at all.

Table 2: Number of Complaints and Peak PM2.5 Concentrations for Pullman, 2000 and 2001.

Date	Number of Complaints	Peak PM2.5 > 20 ug/m3?	Comment
April 17, 2000	1	No	Measured PM2.5 very low for 4/17, and previous 3 days
April 25, 2000	1	No	
August 23, 2000	2	Yes	Very high peak (> 90) and mean PM2.5 (>25)
September 8, 2000	1	No	
September 14, 2000	1	Yes	Peak was near 60 ug/m3, also over 20 on day before
October 6, 2000	1	Close to 20	
October 11, 2000	1	Yes	Oct 9 – 12 had elevated (> 20) concentrations
October 26, 2000	0	Yes	Oct 24 – 27 had elevated concentrations but no complaints
March 20, 2001	1	No	
March 26, 2001	3	No	Complaints were about smoke blowing across the road north of Pullman – did not affect air quality in Pullman
Apr 10, 2001	1	No	Apr 9 had somewhat high peak value
Apr 12, 2001	1	No	
Apr 17, 2001	1	No	
Apr 18, 2001	1	No	
Apr 20, 2001	1	No	
Apr 26, 2001	1	No	Apr 23 – 27 had somewhat higher peak values, but none > 20
Sept 6, 2001	1	No	

Sept 12, 2001	4	Yes	Very high peak value, over 120 ug/m3
Sept 13, 2001	3	Yes	
Sept 14, 2001	1	No	PM2.5 still somewhat elevated compared to baseline
Sept 17, 2001	1	No	Somewhat elevated
Sept 18, 2001	2	Yes	PM2.5 > 40
Sept 19, 2001	11	Yes	Seems related to day before
Sept 20, 2001	1	No	PM2.5 still elevated. Period of Sept 10 – 20 in general had elevated PM2.5 levels compared to “normal”
Sept 25, 2001	1	Yes	Sept 24-25 had elevated levels

Complaints in the spring seem to be especially less correlated to air quality measurements at the local monitoring site, compared to those in the fall. Although much more total acres were burned in Whitman County in the spring of 2001 than in the fall of 2001, due at least in part to the much lower number of burn days available, the air quality impact was more quantifiable in the fall. This may be due to overall poorer ventilation conditions in the fall compared to the spring, or to the larger number of acres burned on a given day, or a combination of both. This suggests that setting a limit on the number of acres burned per day, at least in Whitman County, and perhaps in nearby, upwind counties, may help reduce the number of complaints.

Trajectory Analyses

In all, 8 dates in 2000 and 2001 were identified from the as occurrences of smoke intrusion in Pullman, WA (i.e., air quality impacts were recorded on monitors in town). It should be noted that the events discussed below do not include the episode of March 26, 2001, for which a field burning north of Pullman caused a traffic hazard from smoke blowing across the highway, since the smoke did not come into town. In 2000, conditions in the Northwest were such that many wildfires burned during the summer, especially in northern or central Idaho, possibly leading to erroneous attribution of some smoke episodes to agricultural burning. In order to determine whether the source of the smoke was from agricultural burning in eastern Washington State or from either forestry or agricultural burning from other regions, further analyses were performed. In the rest of this section, these dates will be examined individually in attempts to identify the source(s) of the smoke. These seven events are summarized in Table 3, below.

Table 3. Summary of Seven Events of Smoke Intrusion in Pullman, WA, in 2000 and 2001.

Date	Complaints	Agric. acres burned	Wildfire acres, locations	Wind direction	Source of smoke
June 29, 2000	No	None reported No burn call	Hanford, 100,000 ac.	SW	Hanford fire
July 22, 2000	No	None reported Burn call for Whitman Co.	North-central Idaho 46,000 ac.	W-SW	Likely ag burning, Whitman Co.
Aug 23, 2000	2 ag smoke	None reported No burn call	Several fires Central, North central Idaho >200,000 ac.	E-SE	Wildfires in Idaho
Sept 14, 2000	2 unspecified	Columbia Co. 1800 ac. CdA Res. 2400 ac.	Several fires Central, North central Idaho ~200,000 ac.	E	Wildfires in Idaho
Oct 9, 2000	None	Columbia Co. >4000 ac.	Several fires Near Salmon, ID	SW	Columbia Co. agricultural fires
Sept 12, 2001	8 smoke	No burn WA CdA Res.	Large fire near Chelan	Low winds, NE - SW	Ag burning on CdA Res.
Sept 19, 2001	10 smoke	Limited burns in Whitman, Walla Walla	Chelan fire 70% contained	SW, moderate winds	Walla Walla ag fire turned wild fire (5000 acres)

These 8 events are discussed in more detail, below.

June 29, 2000.

On the morning of June 29, 2000, hourly PM_{2.5} concentrations as measured by nephelometers exceeded 50 ug/m³ at both the Pullman and Colfax monitors, with the peak concentrations occurring at 10:00 am PST. The timing of the peak on this date was the same at both Pullman and Colfax, and the magnitude of the peak concentration, as well as the average concentration for the day, was very similar for both locations as well, indicating that this was a fairly widespread event. During this time, the Two Fork wildfire was burning on the US Department of Energy Hanford site. The wildfire was estimated to be over 100,000 acres in size and was captured by high-resolution satellite images. A back trajectory analysis for the 10:00 am peak in Pullman was performed using HYSPLIT with EDAS archived forecast meteorological data (80 km resolution). The back trajectories for the ground-level concentration come from the southwest, or consistent with a source near the Tri-Cities area. Thus, this trajectory analysis suggests that the smoke observed in Pullman and in Colfax was related to the Hanford wildfire.

July 22, 2000.

On the afternoon (6:00 pm PST) of July 22, 2000, high PM_{2.5} concentrations (over 75 ug/m³ per the nephelometer readings) were observed at both Pullman and Colfax monitors. This episode lasted for four hours. No smoke complaints were registered, and no agricultural burning was reported in eastern Washington, although a burn call for the day authorized agricultural burning in Whitman County between 10 am and 6 pm. During this period, Burgdorf Junction (6,000 acres) and Clear Creek (40,000 acres) wildfires were burning in north central Idaho. Back trajectory analyses using HYSPLIT indicated that the air parcels reaching Pullman on July 22 at 6:00 pm PST came from the west to southwest. No burning activities were reported from that general direction, however since post-burn reports were voluntary for fall of 2000, the lack of reports for this day do not rule out agricultural burns in eastern Washington as the source of the smoke. It is also possible that archived forecast meteorological data were not accurate for this day, or that burning in allowable areas did not result in citizen complaints for this day. In summary, the source of the smoke impacting Pullman and Colfax cannot be definitively assessed from this analysis, however it is likely that the smoke came from agricultural burning in eastern Washington.

August 23, 2000.

On the morning (10:00 am PDT) of August 23, 2000, high levels of PM_{2.5} (95 ug/m³ from the nephelometers) lasting for three hours were observed from the instruments located in Pullman and in Colfax. No agricultural burns were reported, and no burn calls (by WDOE) were issued for the day. There were, however, two smoke complaints reported in Pullman that attributed the smoke to agricultural burning. Also, several large wildfires were burning in central Idaho and western Montana. Table 4 summarizes the fires in the region on this date. Some of these fires are also evident from a satellite image for this day. Based upon the absence of burn calls and burn reports for the day, along with the wildfires in central Idaho, we hypothesized that the source of the smoke on August 23, 2000 was from the wildfires to the east and southeast. This hypothesis was tested using a back-trajectory analysis. The results of this analysis are consistent with the hypothesis that the smoke originated from wildfires in central Idaho.

Table 4: Wildfire updates as Reported From the Forest Service and Salmon-Challis Fire Information Center for August 23, 2000.

Wildfire	Location	Size, acres	% Contained as of 8/23/00
Clear Creek Fire	Central Idaho	171,505	36
Rankin Creek Fire	Central Idaho	6,700	80
Morse Creek Fire	Central Idaho	2,725	11
Wilderness Fires	Central Idaho	94,200	Not contained
Marling Spring Fire	North-Central Idaho	1,000	Not contained

Source: USDA Forest Service

September 14, 2000.

During the afternoon (5:00 pm PST) of September 14, 2000, PM_{2.5} concentrations exceeded 50 ug/m³ as determined by the nephelometer in Pullman. Concentrations measured by TEOM from WSU peaked at 78 ug/m³. Although WDOE issued a no burn call for the day, there were over 2000 acres burned in Adams and Columbia Counties, and another 2400 acres burned on the

Coeur d'Alene Indian Reservation (Table 5). In addition, several large wildfires were also burning in north central Idaho, involving more than 206,000 acres. Two complaints were registered, but they did not specifically mention agricultural burning or smoke.

Table 5. Agricultural Burn Activities Reported for September 14, 2000 in Eastern Washington and Northern Idaho.

Fire Location	Number of Fires	Reported Acreage
Adams County	1	180
Columbia County	8	1849
<u>Coeur d'Alene Reservation</u>	<u>N/A</u>	<u>2411</u>
Total		4,440

Source: Fall 2000 Burn Reports

Based on this information, it was not clear whether the air quality impacts measured by the monitors in Pullman were due to agricultural smoke or from wildfire smoke. A trajectory analysis was performed to further examine this question. The results suggest that the smoke came from the east, from central and north central Idaho, or consistent with the smoke coming from wildfires in Idaho.

October 9, 2000.

During the evening of October 9, 2000, levels of PM_{2.5} exceeded 65 ug/m³ according to the nephelometers at both Pullman (8:00 pm PST) and at Colfax (9:00 pm). High levels persisted for about 3 hours, but no complaints were registered. During the day on October 9, numerous agricultural burns were reported for Columbia County, involving more than 4,000 acres. Wildfires were still burning in northern Idaho, approximately 12 miles west of Salmon, Idaho. The results of a back-trajectory analysis indicated winds from the southwest, and were consistent with smoke from agricultural burning in Columbia County impacting Pullman on this day.

September 12, 2001.

During the evening of September 12, 2001, very high levels of PM_{2.5} were observed at the Pullman (6:30 pm PDT) and Moscow, ID (5:00 pm PDT) monitoring sites, and conditions lasted for more than 3 hours. Peak PM₁₀ levels in Pullman reached 214 ug/m³, and in Moscow, the peak hourly concentration was 210 ug/m³. Eight formal complaints were reported for this episode, linking the smoke to agricultural burning in Idaho. For this day, for the entire state of Washington, a no-burn call was issued, however on the Coeur d'Alene reservation, a burn call was declared between 10:00 am and 3:00 pm. Wildfires were still burning in the region, including the Chelan-Sawtooth Wilderness in central Washington state. Ventilation conditions were poor throughout the day according to the archived MM5 forecasts. Surface winds were light and from the northeast to northwest for most of the day. The back-trajectory analyses were also consistent with the source of the smoke coming from the direction of the Coeur d'Alene reservation.

September 19, 2001.

The prevailing winds in the early morning (12:30 am) were moderate and out of the southwest. PM10 concentrations peaked at 200 ug/m3 in Pullman, and remained high for about 2 hours. Eleven formal complaints were registered. Burns are allowed during the daytime in Washington, and the previous day had been a positive burn call day for a limited number of acres in certain areas, including 75 acres in Walla Walla county, and 100 acres in Whitman county. A Walla Walla fire burned out of control, however, growing to 5,000 acres overnight. During the evening of the 18th, the favorable ventilation conditions deteriorated. The results of a hand calculated back-trajectory analysis were consistent with the source of the smoke intrusion in Pullman coming from the Walla Walla fire.

Conclusions

Changes in the WDOE smoke management program appear to be having a positive effect on air quality in the region. There has been a reduction in the number of acres burned from 2000 to 2001. The mandatory burn reporting will assure that data will be assembled so that air quality trends can be analyzed, for further improvements in smoke management.

There is no clear correlation between air quality complaints in Pullman and apparent air quality impacts due to agricultural burning in eastern Washington and northern Idaho. Complaints were sometimes registered on days for which no clear impact was observed at the downtown nephelometer. On the other hand, there were also several observations of air quality impacts in Pullman that were attributed to agricultural or other fire activities in the region, for which there were no complaints registered. We suspect that, as the public becomes more aware of the "hotline" more complaints will be registered, and the hotline will become a useful tool for tracking the success of the smoke management program.

It appears that several smoke intrusion episodes in Pullman were incorrectly attributed to agricultural burning, either in eastern Washington or northern Idaho. This especially occurred in the fall of 2000, during which time forest wildfires occasionally impacted the entire region. Of the worst two episodes that occurred in the fall of 2001, one was due to an agricultural field burn that got out of control and grew to nearly 5000 acres in Walla Walla county, and the other was due to field burning that took place in northern Idaho, likely on the Coeur d'Alene Indian Reservation. This suggests the need for coordination between state and local agencies involved in analyzing meteorological conditions and making burn calls, so that the entire region is considered. Given the number of agencies independently evaluating meteorological conditions, there is a good opportunity for sharing forecasts and comparing burn calls.

Most complaints and most measurable impacts appear to occur in the fall. This is likely due in part to the limited number of days available for burning, which results in large numbers of acres burned on any given burn day. This suggests that a limit on the total number of acres burned on a single day may be warranted. Smoke management programs that limit the burn "window" or that do not allow burning on weekends, for example, reduce the number of potential burn days even further, and thus exacerbate the problem in the fall.

The current air quality standards for particulate matter, based upon 24-hr averages, may not adequately protect human health in regions where short-term, very high concentrations of smoke are possible. The health effects of short-term, high concentrations of PM are not well-

understood, and require study. In particular, exposure assessment and health effects of exposure to particulate matter from agricultural burning need to be better understood.

A good smoke management program in Washington State, alone, will not completely alleviate the air quality problems associated with smoke in the region. Without coordination and cooperation from the appropriate agencies in Idaho, including the Coeur d'Alene Nation and possibly other Native American groups (e.g., Nez Perce), there will likely continue to be air quality impacts due to agricultural smoke in Pullman. Finally, regional forest wildfires may on occasion continue to impact the airshed. Coordination with the Forest Service to manage biomass smoke from both forestry and agricultural prescribed burning should be a long-term goal.